VEHICLE PERFORMANCE IN FULL-FRONTAL CRASH TESTS WITH SMALL FEMALE AND MID-SIZED MALE OCCUPANTS

Matthew R. Maltese
Aloke Prasad
Nathaniel Beuse
William T. Hollowell
NHTSA / DOT
USA
Paper Number 414

ABSTRACT

Thirty-four model year 2001 vehicles were tested in full frontal rigid barrier impacts at 40, 48 and 56 kmph with either belted or unbelted 5th Female, or belted 50th Male, Hybrid III occupants. The conclusions are as follows: Head contact with the windshield and header were observed in the unbelted 50th percentile male tests, indicating that the air bag alone was not sufficient to restrain the mid-sized male occupant. Head contacts with interior hard points infrequently resulted in HIC and/or Nij exceeding their respective IARVs. Increasing the test speed did not necessarily lead to an increase in HIC or Nij measurements, for the 5th female occupant. Abdomen-to-steering wheel contact was observed in this test series, however dummy abdomen instrumentation limitations precluded injury assessment.

INTRODUCTION

In March of 1997, the National Highway Traffic Safety Administration (NHTSA) provided an alternative to the mandatory 48 kmph unbelted 50th percentile male frontal impact barrier test in Federal Motor Vehicle Safety Standard (FMVSS) 208 to allow vehicle manufacturers to quickly provide vehicle air bag designs that were less likely to injure out-of-position (OOP) small female and child occupants [1]. In its place, NHTSA issued a rule allowing manufacturers to comply with either the unbelted barrier test or an unbelted sled test wherein the vehicle is placed on a sled buck and accelerated through a prescribed 48 kmph sled pulse. In either case, the vehicle manufacturer must not exceed injury thresholds for the head, neck, thorax and legs on the 50th percentile dummies in the right and left front seating positions. NTHSA then embarked on a research program to study frontal impact within the context of protecting adult and child occupants. This research yielded injury criteria for adult and child occupants for the head, neck, chest and legs [2], and the development of crash test procedures to evaluate vehicle performance [3].

In the year 2000, the FMVSS 208 Advanced Air bag Rule was issued which, in addition to regulating out-of-position (OOP) tests with child and small female occupants, requires a battery of crash tests to ensure protection for the belted and unbelted 50th male and 5th female occupants (See Table 1). As part of the agency's commitment to monitor the performance of the vehicle fleet during the phase-in of the rule, Summers et al. [4] conducted crash tests with MY 1998 and 1999 vehicles with belted and unbelted small female and mid-male dummies, and illustrated the need for optimized frontal crash protection for occupants of different sizes and seat positions. Beuse et al. [5] analyzed the performance of 5th percentile belted female dummies in full frontal crash tests with MY 2001 vehicles (a subset of the series presented here) and had conclusions similar to Summers et al.

Table 1

FMVSS 208 Advanced Air bag Rule Vehicle Crash Test Requirements. (Phase-in begins September 1, 2003)

Test Speed (kmph)	Barrier	Impact Angle (degrees)	Belt	Dummy
32-40	Full Rigid	+30 to -30	No	50th Male
32-40	Full Rigid	0	No	5th Female
0-40	Offset Deformable	0	Yes	5th Female
0-48	Full Rigid	0	Yes	50th Male
0-48	Full Rigid	0	Yes	5th Female
0-56*	Full Rigid	0	Yes	50th Male

* phase-in begins in MY2007

As a follow on to the Summers and Beuse studies, this paper presents results of a series of full frontal crash tests with the belted and unbelted small female and mid-sized male hybrid III dummies. The vehicles tested were sold before the FMVSS 208 Advanced Air bag Rule took effect, and thus they had not been certified to meet the requirements outlined in Table 1. Nevertheless, NHTSA chose to evaluate these vehicles to monitor the progression of the vehicle fleet as the rule takes full effect. OOP testing with these same vehicles is presented in Prasad et al.[6]

Table 2
Test Matrix for Driver and Passenger Crash Tests (X indicates test was conducted.)

	Occupant =>	5th Female			50th Male	
	Restraint =>	Unbelted		Belted	Unbelted	
	Speed (kmph) =>	40	48	56	40	48
Vehicle	Class	Mass (kg)					
Chevy Impala	Medium Pass. Car	1566	x	x	x	x	x
Dodge Caravan	Minivan	1761	x	x	x	x	x
Ford Escape	SUV	1391	x	x	x	x	x
Ford F-150 Pickup	Pickup Truck	2122	x	x		x	x
Honda Accord	Medium Pass. Car	1399	x	x	x	x	x
Toyota Echo	Light Pass. Car	982	x	x	x	x	x
Nissan Maxima	Medium Pass. Car	1470			x		
Dodge Durango	SUV	2140			x		
Nissan Sentra	Compact Pass. Car	1255			x		
Ford Windstar	Minivan	1875			x		
Honda Civic	Compact Pass. Car	1146			x		

METHODS

Thirty-four vehicles were purchased from dealer lots close to the test facilities. Vehicles with advanced air bag technology such as dual or multi-stage inflators were specifically considered for this test program. Then vehicle sales volume and vehicle type were considered and the final test matrix was constructed. The vehicles were tested in accordance with procedures outlined in FMVSS 208 Sections 14, 15 and 17, except that the combination of dummy size, seat belt use, and test speed was varied for these research tests. Pre-test measurements quantified distance between various occupant body parts to vehicle interior components (i.e. Chest-to-Steering wheel). The vehicles were placed on a test track and accelerated to the prescribed test speed. The test vehicles struck a rigid barrier with the long axis of the vehicle perpendicular to the barrier face. The barrier engaged the entire front of the vehicle (no offset). Test speeds were either 40, 48 or 56 kmph with either a 5th Female or 50th Male Hybrid III dummies. The 56 kmph belted 5th female was of particular interest, so additional tests were conducted in this mode (See Table 2). The following injury criteria were calculated in accordance with FMVSS No. 208 Advanced Air bag Rule:

- HIC15 – The Head Injury Criteria with a 15 millisecond time window limit.
- Nij neck injury criteria.
- Maximum Neck Tension
- Maximum Neck Compression
- Chest Acceleration – 3 millisecond clip of the resultant chest acceleration.
- Chest Deflection – The maximum chest deflection.
- Femur Force – Maximum Axial Femur Force

For some of the figures in the paper, the injury criteria were normalized by dividing by their corresponding injury assessment reference values (IARV) in FMVSS 208 Advanced Air bag Rule (See Table 3).

Table 3
FMVSS 208 Advanced Air bag Injury Assessment Reference Values

		IARV	
Injury Criteria	Units	5th Female	50th Male
HIC15	-	700	700
Nij	-	1	1
Neck Tension	Newtons	2620	4170
Neck Compression	Newtons	2520	4000
Chest Acceleration	g	60	60
Chest Deflection	Millimeters	52	63
Femur Force	Newtons	6805	10008

Transfer paint was applied to parts of the dummy and vehicle interior, leaving witness marks from which occupant contacts could be evaluated post-crash. Fifteen or more high-speed cameras documented vehicle and occupant kinematics during the event.

RESULTS

Head Injury

The HIC15 responses were all below the thresholds for injury with exception of two tests (see Appendix A, Table A1 & A2). In those tests no head strikes were found other than on the air bag (see Appendix A, Table A3 & A4). In general, HIC could not be correlated with interior head strikes to hard surfaces (see Figure 1). Hard surface contacts were defined as points

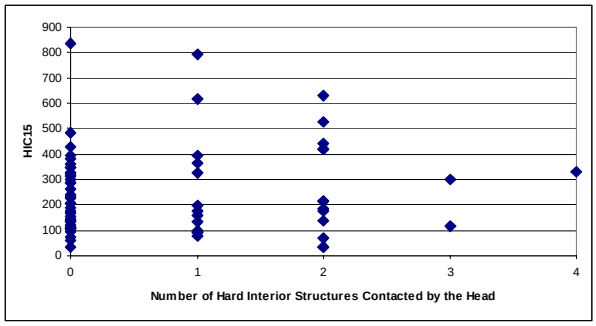

Figure 1. HIC15 vs. the Number of Hard Interior Structures Contacted by the Head during the crash, for both occupants in all 34 crash tests. A hard interior structure is defined as anything but the air bag, seatback or head restraint.

of head contact other than the air bag, seat back, and head restraint. For the driver dummy, the average HIC increased with increasing test speed, regardless of belted condition. The variability of the HIC also increased with increasing test speed, on the driver's side with both the 5th and 50th occupants (See Appendix A, Table A1).

For the six vehicle makes/models that were tested in each of the three crash conditions with the 5th female, the driver HIC results did not agree as to which of the test conditions was the most severe (See Figure 2). The 5th female

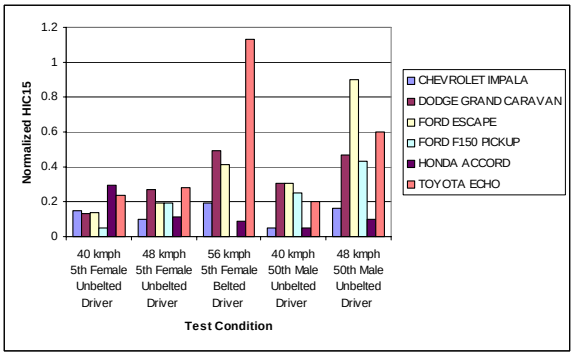

Figure 2. Normalized HIC15 vs. Test Condition for the Driver Side Occupant

Accord HIC's were highest in the 40 kmph test; the F150 HIC's were highest in the 48 kmph test[1]; and the Echo, Escape, Grand Caravan and Impala HIC's were highest in the 56 kmph belted condition. If only 5th female unbelted tests are considered, there still is no clear trend, as the Impala and Accord HIC's were highest in the 40 kmph test while the Grand Caravan, Escape, F150 and Echo HIC's were highest in the 48 kmph tests. A clearer trend is exhibited in the 50th percentile tests as, for each vehicle considered, the HIC's were all highest in the 48 kmph test condition, when compared with the 40 kmph tests.

On the passenger side, the 5th female Accord HIC's were highest in the 40 kmph test; the Impala, Grand Caravan and F150 HIC's were highest in the 48 kmph test[1]; and the Echo and Escape HIC's were highest in the 56 kmph belted condition (See Figure 3). Like the driver side results, the 50th male HIC's in the 48 kmph test condition were higher than that of the 40 kmph tests.

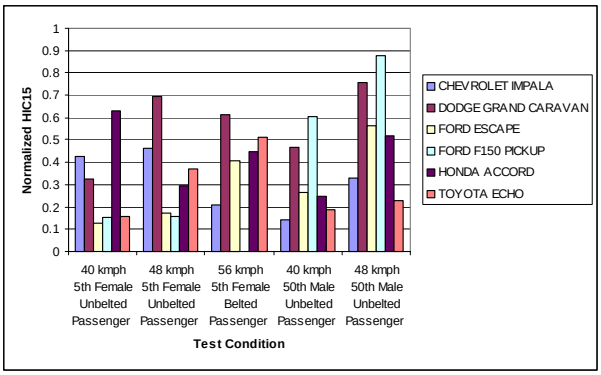

Figure 3. Normalized HIC15 vs. Test Condition for the Passenger Side Occupant

The majority of head contacts in the 5th female driver's side tests were to the air bag and seat; however, the 50th male tests resulted in a significant number of contacts with the windshield, steering wheel and other interior structures (See Figure 4). Similar results were observed on the passenger side, with a significant number of windshield strikes in the 50th male, and either air bag, seat, or other interior contacts in the 5th female (See Figure 5).

[1] The 56 kmph belted test was not conducted with the F150.

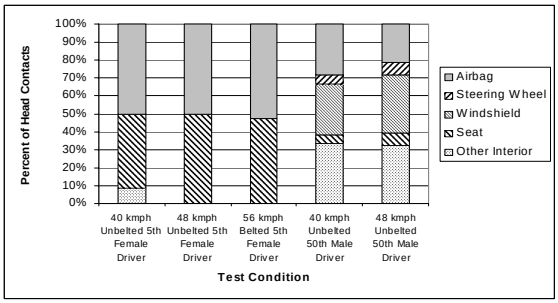

Figure 4. Percent of Head Contacts vs. Test Condition for the Driver Dummy

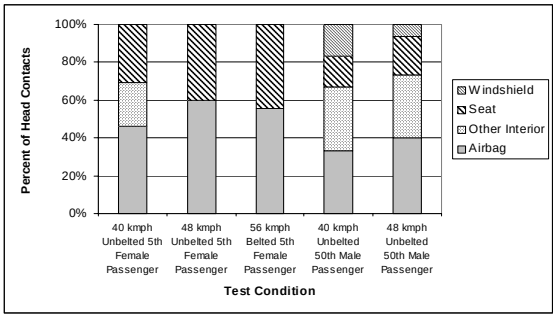

Figure 5. Percent of Head Contacts vs. Test Condition for the Passenger Dummy

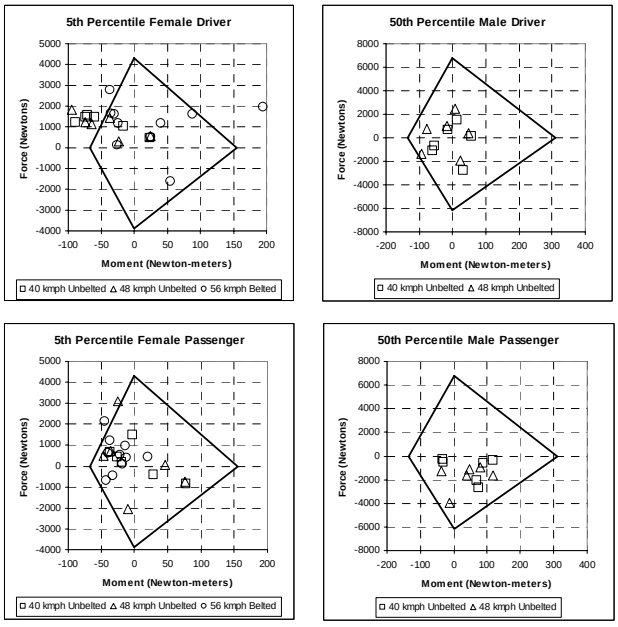

Figure 6. Upper neck Z-force vs. Y-moment at time of maximum Nij, sorted by occupant type and location, and crash severity.

Of all the HIC values calculated, 9 had durations less than 15 milliseconds; however, no correlation is observed between duration, the HIC15, or head contacts with hard points on the vehicle interior. (Appendix A, Table A1 through A4)

Neck Injury

The moment and tension at the head-neck junction at the time of maximum Nij is plotted in Figure 6. The majority of the 5th female Nij values that exceeded the IARV occurred in the unbelted driver occupant, and there were no Nij values exceeded the IARV for the 50th male occupant. For the 5th female occupant, the majority of maximum Nij's are in the tension-extension mode (positive force and negative moment), including all but one of the cases where the IARV was exceeded, which occurred in the tension-flexion mode. For the 5th female driver occupant, a greater portion of Nij values exceeded the IARV occurred in the unbelted 40 kmph (4 values exceeded the IARVs out of 6 tests) and 48 kmph (3 values exceeded the IARVs out of 6 tests), than in the 56 kmph belted test (2 values exceeded the IARVs of 10 tests). The 50th male occupant Nij's were mixed in all modes for the driver, and confined to either compression–extension or compression-flexion for the passenger occupant. There were no cases of Nij that exceeded the IARV in tests with the male occupant. In all but one case, if the independent IARV's for neck tension or compression were exceeded, Nij also exceeded its IARV. The one exception was the only axial neck compression failure in the entire series.

Nij does not appear to have functional relationship to contact with hard points on the vehicle interior (See Figure 7). Also, Nij did not correlate with the distance between the chest and steering wheel (Appendix A, Table A5).

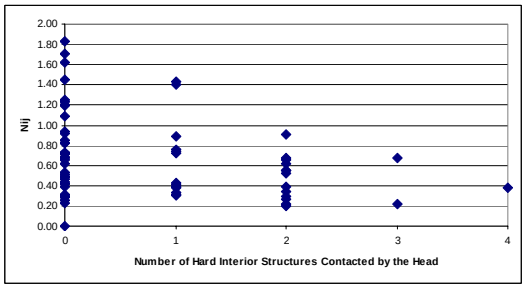

Figure 7. Nij vs. the Number of Hard Interior Structures Contacted by the Head during the crash, for both occupants in all 34 crash tests.

Looking at the same vehicle tested in each of the five test conditions, the 5th female driver Escape, Accord and Echo Nij's were highest in the 40 kmph test condition; the Grand Caravan and F150 Nij's were highest in the 48 kmph test; and the Impala Nij's were highest in the 56 kmph belted test condition (See Figure 8). The three Grand Caravan 5th female driver Nij's were higher than any of the other

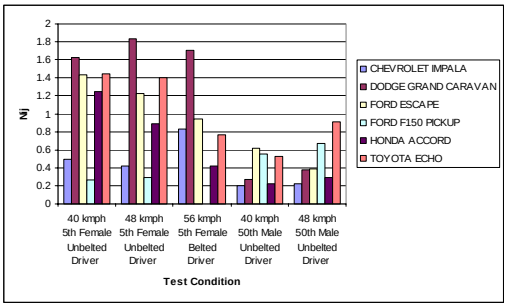

Figure 8. Driver Nij's sorted by crash condition, occupant type, and restraint, for different vehicles.

Nij's in the other vehicles tested. The driver 50th male test Nij's were all slightly below the IARV; and in all but one case (Escape) the 40 kmph Nij was lower than the associated 48 kmph Nij with the same vehicle. On the passenger side, the Impala and Escape 5th female Nij's were highest in the 40 kmph test, the Grand Caravan, Accord, F150[1] and Echo Nij's were highest in the 48 kmph test (See Figure 9). The passenger 50th male tests were all below the IARV; and in all but one case (Escape) the 48 kmph Nij was lower than the associated 40 kmph Nij with the same vehicle.

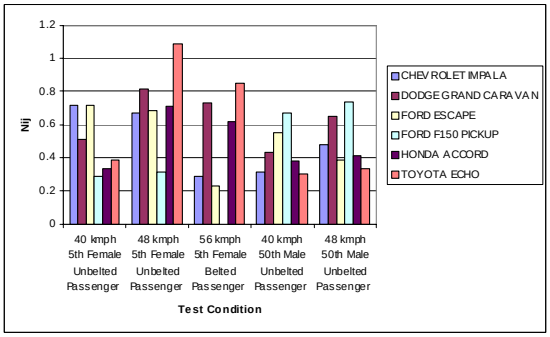

Figure 9. Passenger Nij's sorted by crash condition, occupant type, and restraint, for different vehicles.

Chest Injury

Driver occupant injury criteria results were as follows: Five exceeded the injury threshold for chest deflection only, one exceeded the injury threshold for acceleration only, and four exceeded both the acceleration and deflection thresholds. On the passenger side, two occupants exceeded the acceleration threshold and none exceeded the deflection threshold (See

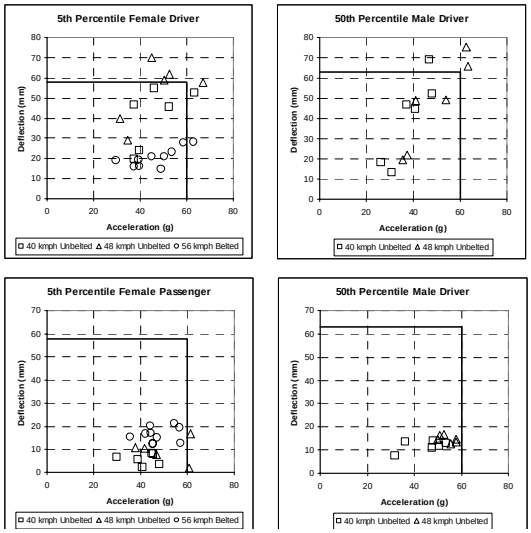

Figure 10. Maximum Central Chest Deflection vs. 3ms Clip Resultant Chest Acceleration, sorted by occupant type and location, and test condition.

Appendix A, Tables A1 & A2 and Figure 10). Looking at the same vehicle tested in each of the unbelted test conditions, the 5th female driver chest acceleration was highest in the 40 kmph test in the Impala and the Accord, and was highest in the 48 kmph condition in the Grand Caravan and Escape. The performance 5th unbelted driver in the echo was roughly the same in the 40 and 48 kmph tests. For the chest accelerations in the 5th unbelted female passenger, the 48 kmph condition was more severe for all vehicles except for the Accord, where the 40 kmph test had the highest chest acceleration (See Figure 11). For the 50th male unbelted driver and passenger, the chest acceleration was always highest in the higher speed test (See Figure 12).

Witness marks from transfer paint revealed dummy contact with the steering wheel. Torso-to-steering wheel contacts were more prevalent in the 5th female belted driver tests at 56 kmph; and direct steering wheel contact was present in

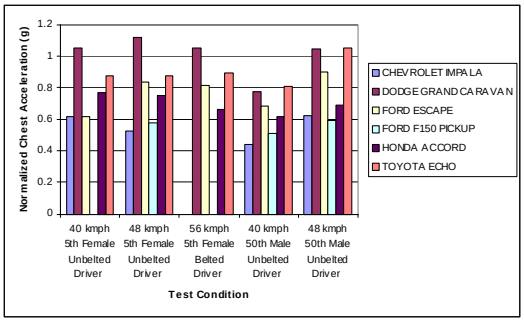

Figure 11. Driver Chest Acceleration sorted by crash condition, occupant type, and restraint, for different vehicles.

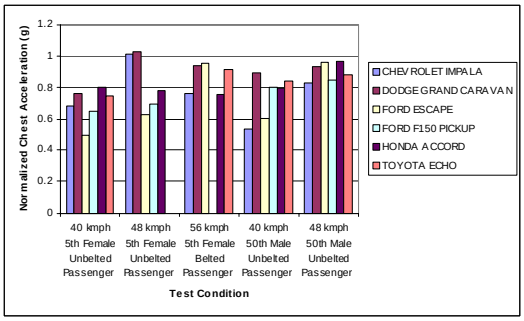

Figure 12. Passenger Chest Acceleration sorted by crash condition, occupant type, and restraint, for different vehicles.

a portion of tests in all test conditions with all dummies. (See Figure 13). However, abdomen and chest contact with the steering wheel did not necessarily lead to chest injury criteria that exceeded the IARV (See Figure 14). The air bag was the primary contact point for the passenger occupant's chest and abdomen (See Appendix A, Table A4).

The chest deflection and viscous criterion (VC) were highly correlated (See Figure 15). One of the 50th male and one 5th female driver occupants exceeded the injury threshold for VC of 1 m/s proposed by Viano[7], and both of these cases also failed chest deflection; there were nine chest deflections that exceeded the IARV, two of which exceeded the IARV for VC.

Femur Injury

Three vehicles exceeded the IARV for the right femur force criterion; all of the left femur forces were below the IARV (See Appendix A, Table A1 and A2). Each test had at least one left and right knee contact with the vehicle interior, and

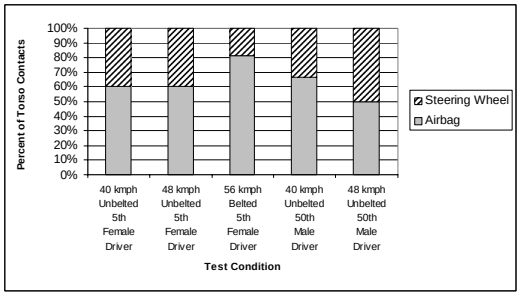

Figure 13. Percent of Driver Torso Contacts by Test Condition.

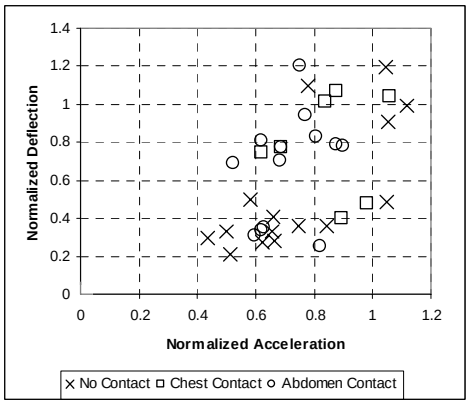

Figure 14. 5th Female and 50th Male Normalized Chest Deflection vs. Normalized Chest Acceleration, for driver occupants with no steering wheel contact, steering wheel contact with the chest, and steering wheel contact with the abdomen.

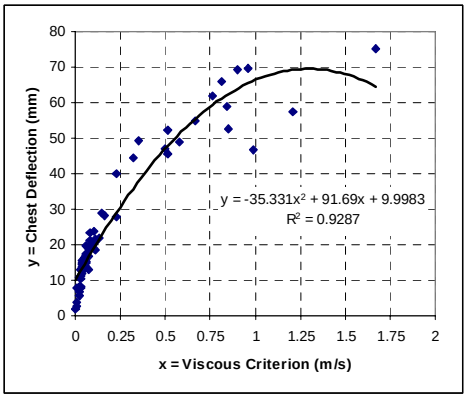

Figure 15. Chest Deflection and Viscous Criterion with best-fit 2nd Order Polynomial Curve and Measure of Goodness of fit (R^2).

the majority of contacts were to the instrument panel or knee bolster.

DISCUSSION

The restraint systems in these crash tests did a good job of mitigating head strikes for the 5th female; however, it is surprising that the air bag alone was not sufficient to mitigate head strikes in the 50th male unbelted tests. Even with such head strikes to hard vehicle interior structures, the HIC and Nij measurements remained unremarkable in the 50th male tests. Indeed, seven of the nine windshield strikes in this condition were of sufficient intensity to result in shattered windshield glass (See Figure 16). It is

Figure 16. Test 3902 50th Male driver occupant showing windshield glass-to-head contact.

possible that the act of shattering the glass absorbs sufficient energy to minimize head / neck injury risk. Nevertheless, we would expect these windshield contacts would result in little or no injury to the would-be human occupant, since the HIC and Nij measurements were all below the injury thresholds specified in FMVSS 208. Also, FMVSS 201 requires free-motion head form impacts to interior points along the header and A-pillar. The padding in these structures required to pass FMVSS 201 may be sufficient to keep the HIC and neck injury values below their IARV's during a head strike in a dynamic frontal impact test.

One would expect that the 48 kmph test is more severe that the 40 kmph test; however, the 5th female HIC and Nij results neither support nor refute this expectation. The 50th male data seem to support the trend that high speed leads to more head and neck injury, holding all other test variables constant. Belt systems, energy absorbing steering rims and columns, load limiters, and perhaps even pretensioners would be expected to behave in a linear or non-linear manner with test speed. Thus, we would expect an increase in injury criteria values with increase in test speed with occupants restrained by the aforementioned means. However, the complexity of air bag deployments combined with full-forward seat position of the 5th female occupant may cause the dummy to interact with an air bag during inflation, and thus lead to the counter-intuitive results displayed in the Figures 2, 3, 8, and 9.

Steering rim-to-abdomen contacts with the 5th percentile female were noted in past joint research tests with Transport Canada. However, the theory for this occurrence stemmed from the fact that the dummy was positioned close to the steering wheel in some vehicles and did not provide enough room for the air bag to deploy downward between the abdomen and the lower rim. In the 50th males tests from this paper where abdomen contact was observed, we theorize that the dummies are driving the air bag toward the top of the steering wheel rim and thus causing lower rim contact with the abdomen.

Evidence of the occurrence, but not injury consequence, of abdominal contact with the steering wheel was prevalent in this test series (See Figure 17). The severity of the abdomen-to-steering wheel interaction could be roughly assessed by the amount and intensity of the paint transfer to the abdomen. However, witness marks require direct contact between the abdomen and steering wheel, thereby eliminating the possibility of detecting contact when an interposer, such as an under-inflated air bag, is present between the torso and steering wheel. The best method for assessing abdominal trauma is via direct measurement of abdominal injury criteria on a biofidelic surrogate. The Hybrid III dummy is equipped with optional iliac crest load cells to detect a lap belt sliding up over the bony pelvis and into the abdominal viscera. However, the Hybrid III it is not instrumented sufficiently to assess blunt abdominal impact in general, such as that which might be induced by the steering

Figure 17. Test 3805 50th Male driver occupant showing transfer paint witness marks indicating steering wheel-to-occupant contact.

wheel. Significant research on the biomechanics of, and injury criteria for, blunt abdominal impact has been conducted over the past two decades [8]. Researchers [9] have developed Hybrid III retrofit hardware to provide a more biofidelic abdomen response; however, the challenge of measuring the deformation of this fluid-filled abdomen was not fully overcome. The THOR [10] dummy has the capability of measuring upper and lower abdominal deflections at three locations and may be a suitable surrogate for future research.

Conclusions

1) Head contact with the windshield and header were observed in the unbelted 50th percentile male tests, indicating that the air bag alone was not sufficient to restrain the mid-sized male occupant.

2) Head contacts with interior hard points infrequently resulted in HIC and/or Nij values that exceeded the IARV.

3) Increasing the test speed did not necessarily lead to an increase in HIC or Nij measurements, for the 5th female occupant.

4) Abdomen-to-steering wheel contact was observed in this test series, however dummy abdomen instrumentation limitations precluded injury assessment.

APPENDIX A, Table A1 – Crash Test Results – Driver

Vehicle and Test Conditons					Head Injury				Neck Injury							Chest Injury						Leg Injury	
NHTSA Test Number	Make	Model	Impact Speed	Seat Belt?	HIC 15	t1	t2	HIC Duration	Nij	Time of Nij	X-Force @ max Nij	Y-Moment @ max Nij	Z-Force @ max Nij	Minimum Neck Force (Compression)	Maximum Neck Force (Tension)	Resultant Chest Accel - 3ms Clip	t1	t2	Maximum Chest Deflection	Viscous Criterion (VC)	Time of VC	Left Femur Force	Right Femur Force
-	-	-	kmph	-	-	ms	ms	ms	-	ms	N	Nm	N	N	N	g	ms	ms	mm	m/s	ms	N	N
5th Female Driver																							
4317	CHEVROLET	IMPALA	40.1	No	103.5	43	58	15	0.49	45	-119.4	-17.0	1031.1	-215.99	1300.37	37.2	62	65	19.8	0.09	0.06	3590	3255
4321	FORD	ESCAPE	40.1	No	94.4	51	66	15	**1.43**	64	-1346.1	-70.8	1579.2	-80.25	1579.85	37.2	66	69	**46.8**	0.99	0.06	2658	1830
4322	DODGE	GRAND CARAVAN	40.1	No	93.3	67	82	15	**1.62**	52	-1985.8	-89.2	1227.3	-46.78	1575.00	**63.2**	73	76	**52.6**	0.85	0.07	4323	4230
4319	HONDA	ACCORD	40.2	No	205.0	49	64	15	**1.25**	62	-1074.5	-60.7	1491.8	-263.03	1831.10	46.0	64	67	**54.7**	0.67	0.06	3552	4235
4320	FORD	F150 PICKUP	40.2	No	35.4	102	117	15	0.26	71	491.6	22.7	499.1	-106.50	625.82	39.7	63	66	23.8	0.10	0.09	3798	4113
4318	TOYOTA	ECHO	40.5	No	167.9	57	72	15	**1.45**	70	-1280.5	-74.1	1466.7	-33.23	1832.02	**52.4**	80	83	**45.6**	0.51	0.08	2117	3631
		Average			*116.6*				*1.08*					*-124.30*	*1457.36*	*46.0*			*40.6*	*0.54*		*3340*	*3549*
		Standard Deviation			*60.4*				*0.57*					*94.035532*	*452.7691*	*10.3*			*15.0*	*0.38*		*805*	*928*
3796	FORD	F150 PICKUP	48	No	136.8	100	115	15	0.29	90	490.3	24.5	555.6	-638.51	640.50	34.8	90	93	29.0	0.15	0.08	4124	5260
3787	HONDA	ACCORD	48.1	No	79.3	36	51	15	**0.89**	44	-578.6	-37.6	1420.9	-321.50	1422.40	45.0	67	70	**69.8**	0.96	0.06	2571	2291
3784	FORD	ESCAPE	48.2	No	134.3	87	102	15	**1.23**	62	-1030.6	-64.8	1135.5	-50.72	1441.56	**50.3**	73	76	**58.7**	0.84	0.06	2545	4163
3786	CHEVROLET	IMPALA	48.2	No	71.3	53	68	15	0.42	102	-50.1	-23.5	286.1	-156.67	528.03	31.4	60	63	39.9	0.23	0.1	4656	3402
3783	DODGE	GRAND CARAVAN	48.3	No	190.2	65	80	15	**1.83**	53	-2065.0	-94.3	1819.5	-85.35	1840.21	**67.1**	67	70	**57.5**	**1.21**	0.06	4643	5063
3785	TOYOTA	ECHO	48.5	No	195.7	51	66	15	**1.40**	67	-1224.1	-74.4	1237.6	-79.53	1776.90	**52.5**	76	79	**61.8**	0.76	0.08	5814	3121
		Average			*134.6*				*1.01*					*-222.0467*	*1274.933*	*46.8*			*52.8*	*0.69*		*4059*	*3883*
		Standard Deviation			*52.7*				*0.59*					*226.25498*	*562.3859*	*13.0*			*15.3*	*0.42*		*1287*	*1159*
3643	NISSAN	MAXIMA	56	Yes	396.0	51	66	15	**0.92**	70	-449.2	-35.7	1661.1	-640.17	1949.76	44.9	58	61	20.8	0.11	0.05	2833	3174
3642	DODGE	DURANGO	56.2	Yes	**836.6**	58	73	15	**1.20**	73	-920.0	-36.4	2799.3	-1209.17	**2836.99**	**58.8**	68	71	27.9	0.23	0.06	1790	2022
3611	HONDA	ACCORD	56.3	Yes	60.8	35	50	15	0.42	118	-417.1	-25.9	141.0	-114.70	1075.17	39.8	66	69	16.4	0.05	0.03	1724	754
3612	NISSAN	SENTRA	56.3	Yes	176.3	49	64	15	0.53	47	-384.1	40.2	1166.3	-40.99	1483.41	39.3	52	55	19.3	0.09	0.05	3034	2729
3644	DODGE	GRAND CARAVAN	56.3	Yes	345.6	54	69	15	**1.71**	55	-2502.2	194.8	1955.4	-766.75	**2112.72**	**63.0**	62	65	28.2	0.16	0.04	2678	2060
3647	TOYOTA	ECHO	56.3	Yes	**794.0**	60	75	15	0.76	158	362.5	54.6	-1599.7	-1691.72	**2271.52**	**53.5**	66	69	23.2	0.08	0.05	540	2036
3648	CHEVROLET	IMPALA	56.3	Yes	136.0	45	60	15	**0.83**	50	-435.2	-30.2	1625.1	-227.44	1629.58	37.5	57	60	15.7	0.04	0.03	3252	3404
3650	FORD	WINDSTAR	56.3	Yes	113.0	58	73	15	0.28	58	178.4	24.2	542.4	-72.72	704.59	29.8	94	97	19.0	0.07	0.04	1795	450
3610	HONDA	CIVIC	56.5	Yes	153.1	40	55	15	0.65	56	-205.7	-25.2	1175.0	-191.90	1514.12	**50.5**	62	65	20.9	0.08	0.03	1340	1176
3646	FORD	ESCAPE	56.5	Yes	288.8	55	70	15	**0.94**	67	-870.0	87.4	1602.6	-393.72	**2287.14**	**49.1**	55	58	14.7	0.04	0.04	898	1914
		Average			*330.0*				*0.82*					*-534.93*	*1786.50*	*46.6*			*20.6*	*0.10*		*1988*	*1972*
		Standard Deviation			*277.0*				*0.41*					*550.15*	*631.55*	*10.3*			*4.7*	*0.06*		*927*	*973*
50th Male Driver																							
3798	CHEVROLET	IMPALA	39.9	No	34.3	85	100	15	0.20	79	739.8	56.1	137.5	-187.63	445.78	26.1	96	99	18.6	0.11	0.09	5633	5358
3804	DODGE	GRAND CARAVAN	39.9	No	212.4	82	97	15	0.27	90	418.1	14.0	1549.9	-456.81	1562.94	46.7	93	96	**69.2**	0.90	0.08	5791	6819
3833	FORD	F150 PICKUP	39.9	No	174.3	100	115	15	0.55	108	976.9	32.7	-2736.5	-2738.31	976.9	30.9	92	95	13.5	0.05	0.09	6687	6961
3817	FORD	ESCAPE	40	No	214.5	85	100	15	0.62	100	576.7	-59.7	-1067.5	-1159.76	1513.25	40.9	84	88	44.5	0.32	0.08	4291	5204
3807	HONDA	ACCORD	40.2	No	34.1	96	111	15	0.22	101	-64.8	-15.9	683.5	-498.60	776.39	37.1	84	87	47.1	0.50	0.07	3980	7260
3805	TOYOTA	ECHO	40.3	No	139.3	83	98	15	0.52	102	135.6	-54.9	-708.9	-783.38	1595.23	**48.3**	83	86	**52.1**	0.51	0.08	3950	6671
		Average			*134.8*				*0.40*					*-970.75*	*1145.08*	*38.3*			*40.8*	*0.40*		*5056*	*6379*
		Standard Deviation			*82.7*				*0.19*					*926.87*	*482.91*	*8.8*			*21.1*	*0.31*		*1140*	*874*
3902	FORD	F150 PICKUP	47.7	No	302.0	76	88	13	0.67	96	-287.2	-76.1	746.4	-2256.22	872.47	35.6	104	107	19.5	0.08	0.09	**8434**	7154
3806	TOYOTA	ECHO	47.8	No	418.7	74	87	13	**0.91**	95	423.9	-92.6	-1353.3	-1397.26	1849.61	**63.5**	89	92	**65.8**	0.81	0.09	7813	**9572**
3848	FORD	ESCAPE	47.8	No	**628.4**	63	74	10	0.39	67	216.8	23.6	-1904.6	-1925.29	906.83	**54.0**	78	82	49.4	0.35	0.09	7536	0
3801	HONDA	ACCORD	47.9	No	70.5	95	110	15	0.29	100	-127.7	-18.5	1028.3	-245.45	1182.55	41.3	70	73	48.8	0.58	0.07	3487	7633
3843	CHEVROLET	IMPALA	47.9	No	114.0	117	132	15	0.22	80	781.2	49.2	406.9	-338.79	788.48	37.6	93	96	22.0	0.13	0.09	4445	5755
3844	DODGE	GRAND CARAVAN	47.9	No	328.3	76	91	15	0.38	79	64.5	6.5	2426.6	-454.96	2427.24	**62.7**	84	87	**75.3**	**1.67**	0.07	7174	**10947**
		Average			*310.3*				*0.48*					*-1103.00*	*1337.86*	*49.1*			*46.8*	*0.60*		*6481*	*6844*
		Standard Deviation			*204.7*				*0.26*					*875.45*	*659.84*	*12.6*			*22.6*	*0.59*		*2014*	*3822*

Note: Cells shown in bold exceeded 80% of injury criteria threshold in FMVSS 208 Advanced Air Bag Rule, and shaded cells exceeded the injury criteria threshold in FMVSS 208 Advanced Air Bag Rule.

APPENDIX A, Table A2 – Crash Test Results – Passenger

Vehicle and Test Conditons					Head Injury				Neck Injury							Chest Injury						Leg Injury	
NHTSA Test Number	Make	Model	Impact Speed	Seat Belt?	HIC 15	t1	t2	HIC Duration	Nij	Time of Nij	X-Force @ max Nij	Y-Moment @ max Nij	Z-Force @ max Nij	Minimum Neck Force (Compression)	Maximum Neck Force (Tension)	Resultant Chest Accel - 3ms Clip	t1	t2	Maximum Chest Deflection	Viscous Criterion (V/C)	Time of VC	Left Femur Force	Right Femur Force
-	-	-	kmph	-	-	ms	ms	ms	-	ms	N	Nm	N	N	N	g	ms	ms	mm	m/s	ms	N	N
5th Female Passenger																							
4317	CHEVROLET	IMPALA	40.1	No	300.1	107	116	8	0.72	113	-11.5	-37.9	657.4	-474.12	1631.18	40.8	114	117	2.5	0.01	0.11	3579	2811
4321	FORD	ESCAPE	40.1	No	89.1	66	81	15	0.72	66	1287.0	77.4	-842.1	-849.13	171.02	29.8	71	75	6.6	0.02	0.07	3913	2888
4322	DODGE	GRAND CARAVAN	40.1	No	227.2	77	92	15	0.51	51	-338.6	-26.8	458.7	-453.72	476.83	45.6	83	89	8.1	0.02	0.07	3683	4006
4319	HONDA	ACCORD	40.2	No	441.2	92	102	10	0.34	123	-49.4	-19.7	211.1	-411.41	639.78	**48.1**	93	96	3.6	0.01	0.09	3307	2689
4320	FORD	F150 PICKUP	40.2	No	106.5	93	108	15	0.29	108	944.7	28.5	-396.1	-419.57	539.33	38.9	96	99	5.6	0.02	0.07	3510	4197
4318	TOYOTA	ECHO	40.5	No	108.6	67	82	15	0.39	96	1884.7	-3.3	1473.7	-271.12	1476.89	44.7	80	83	8.3	0.03	0.07	3259	4625
			Average		*212.1*				*0.50*					*-479.86*	*822.51*	*41.3*			*5.8*	*0.02*		*3542*	*3536*
			Standard Deviation		*139.6*				*0.19*					*194.41*	*589.86*	*6.5*			*2.4*	*0.01*		*243*	*838*
3796	FORD	F150 PICKUP	48	No	111.1	86	101	15	0.31	86	1020.5	45.8	67.4	-136.86	438.93	41.7	88	91	10.3	0.03	0.07	4134	6190
3787	HONDA	ACCORD	48.1	No	206.0	63	78	15	0.71	102	380.5	-36.4	699.5	-527.03	742.06	46.7	72	75	7.8	0.03	0.06	4692	3776
3784	FORD	ESCAPE	48.2	No	120.2	64	79	15	0.68	65	1399.3	76.2	-743.3	-785.12	505.85	37.9	76	80	10.8	0.02	0.06	4038	3933
3786	CHEVROLET	IMPALA	48.2	No	324.4	102	109	7	0.67	103	1089.0	-9.9	-2036.4	**-2036.36**	854.68	**60.9**	105	108	1.9	0.00	0.11	3880	3471
3783	DODGE	GRAND CARAVAN	48.3	No	486.2	74	89	15	**0.82**	49	-659.0	-47.4	496.2	-525.29	726.74	**61.5**	84	87	16.8	0.06	0.07	4740	4100
3785	TOYOTA	ECHO	48.5	No	259.8	63	78	15	**1.09**	91	1635.9	-24.9	3090.2	-250.61	**3096.42**				13.0	0.07	0.07	4509	**8147**
			Average		*251.3*				*0.71*					*-710.21*	*1060.78*	*49.7*			*10.1*	*0.04*		*4332*	*4936*
			Standard Deviation		*141.1*				*0.25*					*688.77*	*1009.37*	*10.9*			*5.0*	*0.03*		*363*	*1848*
3643	NISSAN	MAXIMA	56	Yes	317.8	62	77	15	**0.82**	139	-200.1	-43.4	-687.1	-687.11	1305.73	44.6	72	75	17.2	0.06	0.03	1713	2611
3642	DODGE	DURANGO	56.2	Yes	325.3	63	78	15	**1.19**	62	-801.6	-45.9	2144.4	-567.13	**2253.05**	44.0	64	67	20.3	0.10	0.05	2659	3685
3611	HONDA	ACCORD	56.3	Yes	311.5	62	77	15	0.62	95	103.2	-33.4	-455.3	-477.05	797.43	45.1	79	82	12.6	0.04	0.03	3766	2903
3612	NISSAN	SENTRA	56.3	Yes	348.0	67	82	15	0.29	83	273.6	-12.9	434.8	-322.93	579.76	47.0	76	79	15.2	0.06	0.07	2994	2449
3644	DODGE	GRAND CARAVAN	56.3	Yes	430.4	66	81	15	0.73	50	-721.3	-39.4	628.8	-168.39	1411.46	**56.7**	66	69	19.6	0.06	0.06	3815	2417
3647	TOYOTA	ECHO	56.3	Yes	359.1	60	75	15	**0.85**	58	-478.2	-37.3	1254.0	-394.01	1493.56	**54.6**	53	57	21.4	0.11	0.05	2502	5252
3648	CHEVROLET	IMPALA	56.3	Yes	146.1	74	89	15	0.29	99	-257.2	-17.6	123.6	-323.51	184.30	45.5	62	65	12.5	0.04	0.06	3118	3231
3650	FORD	WINDSTAR	56.3	Yes	382.0	76	91	15	0.44	101	-80.1	-14.3	961.1	-117.02	961.08	35.4	94	97	15.6	0.05	0.04	2247	2044
3610	HONDA	CIVIC	56.5	Yes	241.4	61	76	15	0.46	75	-148.6	-22.4	550.8	-154.94	590.36	42.3	69	72	17.0	0.06	0.02	2270	4320
3646	FORD	ESCAPE	56.5	Yes	285.5	58	73	15	0.23	41	214.5	19.3	455.2	-522.24	737.74	**57.1**	52	55	12.8	0.03	0.04	4108	2224
			Average		*314.7*				*0.59*					*-373.43*	*1031.45*	*47.2*			*16.4*	*0.06*		*2919*	*3114*
			Standard Deviation		*78.7*				*0.31*					*191.42*	*595.14*	*6.9*			*3.3*	*0.03*		*785*	*1029*
50th Male Passenger																							
3798	CHEVROLET	IMPALA	39.9	No	97.7	94	109	15	0.31	126	509.3	-30.8	-522.0	-578.98	545.9	31.9	96	99	7.7	0.01	0.12	4274	3637
3804	DODGE	GRAND CARAVAN	39.9	No	326.3	90	105	15	0.43	85	1548.3	116.8	-346.1	-1126.39	803.24	**53.6**	94	97	13.0	0.04	0.1	**9054**	**8484**
3833	FORD	F150 PICKUP	39.9	No	421.4	97	104	7	0.67	101	1784.5	73.6	-2678.0	-2687.01	773.23	47.8	98	101	14.0	0.05	0.09	6620	6624
3817	FORD	ESCAPE	40	No	185.3	86	101	15	0.55	95	1380.1	69.3	-2029.4	-2031.25	310.87	36.1	86	89	13.7	0.04	0.07	5371	3850
3807	HONDA	ACCORD	40.2	No	174.2	82	97	15	0.38	87	1770.8	88.6	-579.8	-1091.44	416.89	47.5	84	87	10.9	0.03	0.09	3929	4897
3805	TOYOTA	ECHO	40.3	No	131.6	80	95	15	0.30	116	552.7	-34.6	-294.9	-735.75	536.11	**50.5**	87	90	11.8	0.04	0.08	6020	7174
			Average		*222.8*				*0.44*					*-1375.14*	*564.37*	*44.6*			*11.9*	*0.04*		*5878*	*5778*
			Standard Deviation		*124.8*				*0.15*					*816.89*	*193.82*	*8.6*			*2.3*	*0.01*		*1859*	*1953*
3902	FORD	F150 PICKUP	47.7	No	**615.1**	75	81	6	0.74	79	1617.9	-13.1	-3944.2	**-4017.88**	1644.12	**50.9**	101	104	16.6	0.06	0.09	6285	5788
3806	TOYOTA	ECHO	47.8	No	159.9	77	92	15	0.33	90	1911.6	47.9	-1111.4	-1111.39	634.1	**52.7**	79	82	16.7	0.07	0.07	6805	7467
3848	FORD	ESCAPE	47.8	No	394.6	66	75	10	0.39	69	1045.2	39.2	-1615.3	-1615.27	882.89	**57.7**	79	82	14.7	0.06	0.07	7197	**13051**
3801	HONDA	ACCORD	47.9	No	363.3	76	91	15	0.41	84	2066.3	79.1	-940.4	-1232.65	1027.05	**57.9**	80	83	13.4	0.05	0.08	6217	5930
3843	CHEVROLET	IMPALA	47.9	No	231.3	90	105	15	0.48	122	759.8	-37.3	-1277.2	-1281.03	825.53	**49.9**	94	97	14.4	0.04	0.11	5552	3704
3844	DODGE	GRAND CARAVAN	47.9	No	528.0	80	95	15	0.65	83	1702.5	117.7	-1676.6	-1676.62	577.32	**55.7**	90	93	12.8	0.03	0.08	**8757**	**9087**
			Average		*382.0*				*0.50*					*-1822.47*	*931.84*	*54.1*			*14.8*	*0.05*		*6802*	*7505*
			Standard Deviation		*172.2*				*0.16*					*1098.24*	*385.86*	*3.5*			*1.6*	*0.01*		*1109*	*3260*

Note: Cells shown in bold exceeded 80% of injury criteria threshold in FMVSS 208 Advanced Air Bag Rule**, and shaded cells exceeded the injury criteria threshold in FMVSS 208** Advanced Air Bag Rule.

APPENDIX A, Table A3 – Interior Contact Points – Driver Side

Vehicle and Test Conditons					Contact Points				
NHTSA Test #	Make	Model	Impact Speed	belt	Head	Chest	Abdomen	Left Knee	Right Knee
-	-	-	KMPH	-					
5th Female Driver									
4317	CHEVROLET	IMPALA	40	No	AB	AB	SW	IP	IP
4321	FORD	ESCAPE	40	No	AB, SV, SB	AB	SW	KB	KB
4322	DODGE	GRAND CARAVAN	40	No	AB, HR	AB	NC	KB	KB
4319	HONDA	ACCORD	40	No	AB, HR	AB	SW	KB	KB
4320	FORD	F150 PICKUP	40	No	AB, HR	AB	NC	KB	KB
4318	TOYOTA	ECHO	40	No	AB, HR	AB	SW	KB	KB
3796	FORD	F150 PICKUP	48	No	AB, HR	AB	NC	IP	IP
3787	HONDA	ACCORD	48	No	AB, HR, SB	AB	SW	IP	IP
3784	FORD	ESCAPE	48	No	AB	SW, AB	NC	IP	IP
3786	CHEVROLET	IMPALA	48	No	AB	AB	SW	IP	IP
3783	DODGE	GRAND CARAVAN	48	No	AB, HR	AB	NC	IP	IP
3785	TOYOTA	ECHO	48	No	AB, HR, SB	AB, SW	NC	IP	IP
3643	NISSAN	MAXIMA	56	Yes	AB, HR	AB	NC	IP	IP
3642	DODGE	DURANGO	56	Yes	AB, HR	AB, SW	NC	IP	IP
3611	HONDA	ACCORD	56	Yes	AB, HR	AB	AB	SC, KB	SC, KB
3612	NISSAN	SENTRA	56	Yes	AB	AB	AB	IP	IP
3644	DODGE	GRAND CARAVAN	56	Yes	AB, HR	AB	NC	SC, KB	SC, KB
3647	TOYOTA	ECHO	56	Yes	AB, HR, SB	AB, SW	NC	SC, KB	SC, KB
3648	CHEVROLET	IMPALA	56	Yes	AB, HR	AB	NC	KB	KB
3650	FORD	WINDSTAR	56	Yes	AB	AB	NC	IP	IP
3610	HONDA	CIVIC	56	Yes	AB, HR	AB	AB	KB	KB
3646	FORD	ESCAPE	56	Yes	AB, HR	AB	SW	SC, KB	SC, KB
50th Male Driver									
3798	CHEVROLET	IMPALA	40	No	AB, SV, HD	AB	NC	IP	IP
3804	DODGE	GRAND CARAVAN	40	No	AB, SV, HL	AB	NC	IP	IP
3833	FORD	F150 PICKUP	40	No	AB, SV, WS, WSS	AB	NC	IP	IP
3817	FORD	ESCAPE	40	No	AB, SV, WSS	AB	SW	IP	IP
3807	HONDA	ACCORD	40	No	AB, WS, SW	AB, SW	NC	IP	IP
3805	TOYOTA	ECHO	40	No	AB, SV, WS, HR	AB	SW	IP	IP
3902	FORD	F150 PICKUP	48	No	AB, SV, SW, WSS	AB	SW	KB	KB
3806	TOYOTA	ECHO	48	No	AB, SV, WSS, HR	AB, SW	NC	IP	IP
3848	FORD	ESCAPE	48	No	AB, SV, WSS, HR	AB	SW	KB	KB
3801	HONDA	ACCORD	48	No	AB, WS, SW	AB, SW	SW	IP	IP
3843	CHEVROLET	IMPALA	48	No	AB, SV, HD, HL	AB	SW	KB	KB
3844	DODGE	GRAND CARAVAN	48	No	AB, SV, WSS, AP, RR	AB	NC	KB	KB

AB = Airbag, SV = Sun Visor, SB = Seatback, HR = Head Restraint, SW = Steering Wheel, KB = Knee Bolster, GB = Glove Box, HL = Head Liner, IP = Instrument Panel, SC = Steering Column, HD = Header, WS = Windshield without Glass Shatter, WSS = Windshield w/ Glass Shatter, AP = A-pillar, RR = Roof Rail Above Side Window, NC = No Contact

APPENDIX A, Table A4 – Interior Contact Points – Passenger Side

Vehicle and Test Conditons					Contact Points				
NHTSA Test #	Make	Model	Impact Speed	belt	Head	Chest	Abdomen	Left Knee	Right Knee
-	-	-	KMPH	-					
5th Female Passenger									
4317	CHEVROLET	IMPALA	40	No	AB, HR	AB	NC	GB	GB
4321	FORD	ESCAPE	40	No	AB, SV, HR	AB	NC	GB	GB
4322	DODGE	GRAND CARAVAN	40	No	AB, HR	AB	NC	GB	GB
4319	HONDA	ACCORD	40	No	AB, SV, HL	AB	NC	KB	KB
4320	FORD	F150 PICKUP	40	No	AB	AB	NC	GB	GB
4318	TOYOTA	ECHO	40	No	AB, HR	AB	NC	KB	KB
3796	FORD	F150 PICKUP	48	No	AB	AB	NC	IP	IP
3787	HONDA	ACCORD	48	No	AB	AB	NC	IP	IP
3784	FORD	ESCAPE	48	No	AB, HR	AB	NC	IP	IP
3786	CHEVROLET	IMPALA	48	No	AB, HR	AB	NC	IP	IP
3783	DODGE	GRAND CARAVAN	48	No	AB, HR	AB	NC	IP	IP
3785	TOYOTA	ECHO	48	No	AB, HR	AB	NC	IP	IP
3643	NISSAN	MAXIMA	56	Yes	AB, HR	AB	NC	GB	GB
3642	DODGE	DURANGO	56	Yes	AB, HR	AB	NC	GB	GB
3611	HONDA	ACCORD	56	Yes	AB, HR	AB	AB	GB	GB
3612	NISSAN	SENTRA	56	Yes	AB	AB	AB	IP	IP
3644	DODGE	GRAND CARAVAN	56	Yes	AB, HR	AB	NC	GB	GB
3647	TOYOTA	ECHO	56	Yes	AB, HR	AB	NC	GB	GB
3648	CHEVROLET	IMPALA	56	Yes	AB, HR	AB	NC	GB	GB
3650	FORD	WINDSTAR	56	Yes	AB	AB	NC	IP	IP
3610	HONDA	CIVIC	56	Yes	AB, HR	AB	AB	GB	GB
3646	FORD	ESCAPE	56	Yes	AB, HR	AB	NC	GB	GB
50th Male Passenger									
3798	CHEVROLET	IMPALA	40	No	AB, SV	AB	NC	IP	IP
3804	DODGE	GRAND CARAVAN	40	No	AB, SV, HR	AB	NC	IP	IP
3833	FORD	F150 PICKUP	40	No	AB, SV, WS, HR	AB	NC	IP	IP
3817	FORD	ESCAPE	40	No	AB, SV, WSS	AB	NC	IP	IP
3807	HONDA	ACCORD	40	No	AB, SV	AB	NC	IP	IP
3805	TOYOTA	ECHO	40	No	AB, SV, HR	AB	NC	IP	IP
3902	FORD	F150 PICKUP	48	No	AB, SV	AB	NC	KB	KB
3806	TOYOTA	ECHO	48	No	AB, SV, HR	AB	NC	IP	IP
3848	FORD	ESCAPE	48	No	AB, SV	AB	NC	KB	KB
3801	HONDA	ACCORD	48	No	AB, SV	AB	NC	IP	IP
3843	CHEVROLET	IMPALA	48	No	AB, HR	AB	NC	KB	KB
3844	DODGE	GRAND CARAVAN	48	No	AB, SV, WS, HR	AB	NC	KB	KB

AB = Airbag, SV = Sun Visor, SB = Seatback, HR = Head Restraint, SW = Steering Wheel, KB = Knee Bolster, GB = Glove Box, HL = Head Liner, IP = Instrument Panel, SC = Steering Column, HD = Header, WS = Windshield without Glass Shatter, WSS = Windshield w/ Glass Shatter, AP = A-pillar, RR = Roof Rail Above Side Window, NC = No Contact

APPENDIX A, Table A5 – Occupant to vehicle interior pre-impact distances - Driver

Vehicle and Test Conditons					Dummy to Vehicle Interior Distances				
NHTSA Test Number	Make	Model	Impact Speed	Seat Belt?	Head-to-Windshield Header	Head-to-Windshield	Chest-to-Dash	Chest-to-Steering Wheel	Knee-to-dash
-	-	-	kmph	-	mm	mm	mm	mm	mm
5th Female Driver									
4317	CHEVROLET	IMPALA	40.1	No	280	608	421	183	105
4321	FORD	ESCAPE	40.1	No	340	563	463	213	70
4322	DODGE	GRAND CARAVAN	40.1	No	337	693	500	220	135
4319	HONDA	ACCORD	40.2	No	275	643	435	211	116
4320	FORD	F150 PICKUP	40.2	No	418	631	553	276	125
4318	TOYOTA	ECHO	40.5	No	270	583	493	229	90
3796	FORD	F150 PICKUP	48	No	361	625	513	238	127
3787	HONDA	ACCORD	48.1	No	311	623	453	205	120
3784	FORD	ESCAPE	48.2	No	317	600	460	220	78
3786	CHEVROLET	IMPALA	48.2	No	290	656	435	210	127
3783	DODGE	GRAND CARAVAN	48.3	No	347	726	527	254	136
3785	TOYOTA	ECHO	48.5	No	273	595	505	232	57
3643	NISSAN	MAXIMA	56	Yes	263	583	444	200	98
3642	DODGE	DURANGO	56.2	Yes	365	682	416	184	92
3611	HONDA	ACCORD	56.3	Yes	312	683	484	247	133
3612	NISSAN	SENTRA	56.3	Yes	292	626	429	210	84
3644	DODGE	GRAND CARAVAN	56.3	Yes	340	752	499	224	162
3647	TOYOTA	ECHO	56.3	Yes	304	601	591	236	115
3648	CHEVROLET	IMPALA	56.3	Yes	284	630	389	150	104
3650	FORD	WINDSTAR	56.3	Yes	372	688	482	228	110
3610	HONDA	CIVIC	56.5	Yes	298	614	471	223	138
3646	FORD	ESCAPE	56.5	Yes	342	591	454	190	69
50th Male Driver									
3798	CHEVROLET	IMPALA	39.9	No	350	635	523	302	166
3804	DODGE	GRAND CARAVAN	39.9	No	368	578	565	300	163
3833	FORD	F150 PICKUP	39.9	No	404	612	591	335	170
3817	FORD	ESCAPE	40	No	375	573	550	309	133
3807	HONDA	ACCORD	40.2	No	340	603	530	330	148
3805	TOYOTA	ECHO	40.3	No	331	557	580	320	145
3902	FORD	F150 PICKUP	47.7	No	429	618	621	364	183
3806	TOYOTA	ECHO	47.8	No	335	523	610	340	137
3848	FORD	ESCAPE	47.8	No	373	585	533	316	128
3801	HONDA	ACCORD	47.9	No	313	570	518	318	132
3843	CHEVROLET	IMPALA	47.9	No	345	620	520	312	165
3844	DODGE	GRAND CARAVAN	47.9	No	394	596	574	320	155

APPENDIX A, Table A6 – Occupant to vehicle interior pre-impact distances – Passenger

Vehicle and Test Conditons					Dummy to Vehicle Interior Distances			
NHTSA Test Number	Make	Model	Impact Speed	Seat Belt?	Head-to-Windshield Header	Head-to-Windshield	Chest-to-Dash	Knee-to-dash
-	-	-	kmph	-	mm	mm	mm	mm
5th Female Passenger								
4317	CHEVROLET	IMPALA	40.1	No	277	604	406	105
4321	FORD	ESCAPE	40.1	No	325	566	457	70
4322	DODGE	GRAND CARAVAN	40.1	No	300	643	646	120
4319	HONDA	ACCORD	40.2	No	255	558	398	65
4320	FORD	F150 PICKUP	40.2	No	380	613	587	122
4318	TOYOTA	ECHO	40.5	No	305	618	513	110
3796	FORD	F150 PICKUP	48	No	370	598	587	130
3787	HONDA	ACCORD	48.1	No	284	607	388	95
3784	FORD	ESCAPE	48.2	No	328	572	436	64
3786	CHEVROLET	IMPALA	48.2	No	290	600	435	117
3783	DODGE	GRAND CARAVAN	48.3	No	310	640	458	136
3785	TOYOTA	ECHO	48.5	No	305	630	530	107
3643	NISSAN	MAXIMA	56	Yes	265	578	508	58
3642	DODGE	DURANGO	56.2	Yes	373	635	437	48
3611	HONDA	ACCORD	56.3	Yes	256	598	376	60
3612	NISSAN	SENTRA	56.3	Yes	256	541	445	50
3644	DODGE	GRAND CARAVAN	56.3	Yes	325	667	463	119
3647	TOYOTA	ECHO	56.3	Yes	301	638	496	48
3648	CHEVROLET	IMPALA	56.3	Yes	299	641	434	88
3650	FORD	WINDSTAR	56.3	Yes	385	719	576	100
3610	HONDA	CIVIC	56.5	Yes	271	541	402	70
3646	FORD	ESCAPE	56.5	Yes	363	621	585	58
50th Male Passenger								
3798	CHEVROLET	IMPALA	39.9	No	334	655	490	160
3804	DODGE	GRAND CARAVAN	39.9	No	356	600	549	195
3833	FORD	F150 PICKUP	39.9	No	394	620	579	179
3817	FORD	ESCAPE	40	No	385	594	551	135
3807	HONDA	ACCORD	40.2	No	320	605	505	128
3805	TOYOTA	ECHO	40.3	No	337	590	514	132
3902	FORD	F150 PICKUP	47.7	No	420	616	631	202
3806	TOYOTA	ECHO	47.8	No	343	538	588	120
3848	FORD	ESCAPE	47.8	No	381	611	549	129
3801	HONDA	ACCORD	47.9	No	310	610	510	135
3843	CHEVROLET	IMPALA	47.9	No	355	660	512	134
3844	DODGE	GRAND CARAVAN	47.9	No	361	585	575	195

REFERENCES

[1] Code of Federal Regulations 2001. "Occupant Crash Protection." 49 CFR Ch. V (10-1-01 Edition) §571.208 S13, National Archives and Records Administration.
[2] Eppinger R., E. Sun, S. Kuppa, R. Saul 2000. "Supplement :Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems – II." NHTSA Docket 1999-6407-144. U.S. Department of Transportation. Washington.
[3] Hollowell, W.T., H.C. Gabler, S.L. Stucki, S. Summers, J.R. Hackney 1999. "Updated Review of Potential Test Procedures for FMVSS No. 208." NHTSA Docket 1999-6407-6. U.S. Department of Transportation. Washington.
[4] Summers, L., W.T. Hollowell, A. Prasad. 2001. "Analysis Of Occupant Protection Provided To 50th Percentile Male Dummies Sitting Mid-track And 5th Percentile Female Dummies Sitting Full-forward In Crash Tests Of Paired Vehicles With Redesigned Air Bag Systems." In Proceedings of the 17th Enhanced Safety of Vehicles Conference. Paper # 338. U.S. Department of Transportation. Washington.
[5] Beuse, N., L. Summers, W.T. Hollowell, T. Rockwell. 2002 "Final Report on the Evaluation of Ten (10) 56 KMPH (35 MPH) Frontal Barrier Tests Using the 5th Percentile Dummy." NHTSA Docket 2001-10687-12. U.S. Department of Transportation. Washington.
[6] Prasad, A., M.Maltese, A.Louden 2003 "Injury Risks from Advanced Air Bags in Frontal Static Out-of-Position Tests" In Proceedings of the 18th Enhanced Safety of Vehicles Conference. Paper #458. U.S. Department of Transportation. Washington.
[7] Lau, I.V. and D.C. Viano 1986. "The Viscous Criterion: Bases and Applications of an Injury Severity Index for Soft Tissues." Proceedings of the 30th Stapp Car Crash Conference. Paper Number 861882. The Stapp Association.
[8]Yoganandan, N., F.A. Pintar, M.R. Maltese 2001. "Biomechanics of Abdominal Injuries." Critical Rev in Biomed Eng 29(2), 175-246.
[9] Rouhana, S.W., A.M. Elhagediab, A. Walbridge, W.N. Hardy, L.W. Schneider. 2001 "Development of a Reusable, Rate-Sensitive Abdomen for the Hybrid III Family of Dummies." Stapp Car Crash Journal, Vol. 45.
[10] Haffner, M., R. Eppinger, N. Rangarajan, T. Shams, M. Artis, and D. Beach. 2001 "Foundations and Elements of the NHTSA THOR Alpha ATD Design." In Proceedings of the 17th Enhanced Safety of Vehicles Conference. Paper #458. U.S. Department of Transportation. Washington.